Benthic Resuspension by Internal Wave Stimulated Global Instability

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LONG-TERM GOAL

The goal of this work is to contribute toward an understanding of how long internal waves on the shelf region affect the optical properties of the water column and to issues related to remote sensing of the coastal ocean.

OBJECTIVE

Our work is directed toward providing a mechanistic understanding of and a predictive basis for processes whereby long internal waves interact with and stimulate resuspension from the bottom boundary. We also seek to provide insight regarding the effect of long internal waves on the vertical distribution of particulates, etc. in the water column and how they impact remote sensing of motions and processes on the shelf region.

APPROACH

Our approach is to develop an understanding of resuspension and particulate transport processes by means of theoretical modeling and numerical simulation. We also interact with field and laboratory investigators and collaborate on data analysis, model validation, and interpretation of results.

WORK COMPLETED

Analysis of topographic resonance for internal waves in sheared currents, together with the associated boundary layer structure, has been analyzed for various realistic thermocline structures. The model thermocline structures analyzed provide a useful basis for a climatology study of long internal wave packets. Theoretical modeling has been completed and numerical simulations are in progress for resuspension stimulated by internal solitary waves in shallow seas. A numerical study of the transmission of spatially-compact beams of internal waves through a critical level was completed.

RESULTS

The coupling between long internal waves and the bottom boundary layer has been examined in considerable detail for one class of waves, namely, those associated with resonant topographic generation and propagation against an oncoming shear flow. This case was selected for initial study because it mimics the class of internal-wave/boundary-layer interaction where definitive evidence of elevated rates of resuspension stimulated by long internal waves was reported (cf., Bogucki et al, 1997). The boundary layer under the footprint of a solitary wave of elevation is found to exhibit a sudden onset of a peculiar dynamics (described in the literature recently as a global instability) as the

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wave amplitude exceeds a threshold value. The global instability in the boundary layer creates regions of coherent vortex structures and locally steep gradients in the bottom stress. An example of the boundary layer structure at sub-critical and super-critical amplitudes and fixed Reynolds number is shown in the attached figures. The boundary layer structure in the sub-critical simulation shown in Figure 1 is entirely steady. The structure in the super-critical case shown in Figure 2 is temporally periodic, although the streamline pattern shown in the figure is of the time-averaged flow. Clearly, a strong vortex structure remains essentially stationary and can effectively interact with the bottom surface to resuspend sedimentary material. We find that the frequency of the boundary layer instability, which is a fully nonlinear dynamics, increases with the boundary layer Reynolds number. The frequency spectrum of the dynamics at a fixed Reynolds number at two points in the flow separated horizontally by about one-quarter of the wave length is shown in Figure 3. Characterization of the boundary layer dynamics at higher Reynolds numbers and consideration of other types of wave packets is continuing.

We have also developed and tested an evolutionary model for long internal waves in the presence of a background baroclinic seiche. It is found that the energy exchange between the seiche and the packet of long internal waves is profoundly affected by relative phase relationships of the seiche and packet. The model is presently being validated against laboratory data from the Centre for Water Research at the University of Western Australia. These results are of pivotal concern in semi-closed seas and lakes.

In further work, we have begun to examine the consequence of propagating packets of long internal waves on the concentration of particulates. Preliminary results show that the passage of a wave packet can create distinct layers of relatively high particle concentration. Work on this effect is perceived to be important to issues of remote sensing and the coupling of internal waves and biology.

In addition, we completed a study revealing that spatially-compact, nearly monochromatic beams of higher frequency internal waves radiating toward a critical layer can experience significant transmission through a critical level. As the spatial width of the beam increases, the critical level absorption increases also and eventually renders the flow below the critical level essentially opaque to radiated waves. This work points out, however, that non-trivial transmission coefficients can be realized for narrow beams incident on a critical level.

IMPACT

The mechanism whereby long internal waves can give rise to elevated rates of resuspension is believed to have applicability to other wave-related events as well where temporally-varying fields interact with surface boundary layers. In this sense, the current effort might lead to a better understanding of the resuspension process in other flow contexts. Certainly the consequences of the spatio-temporal hydrodynamic processes being studied in this effort for particulate transport and the creation of layers of elevated concentration of particulates is believed to be of particular significance for optics and remote sensing.

REFERENCES

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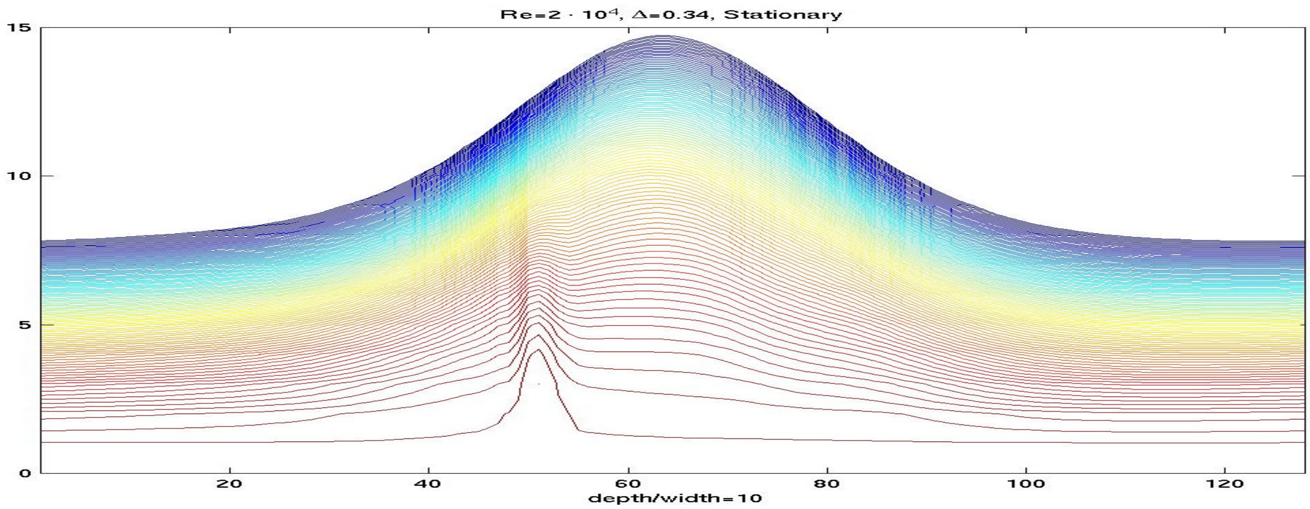

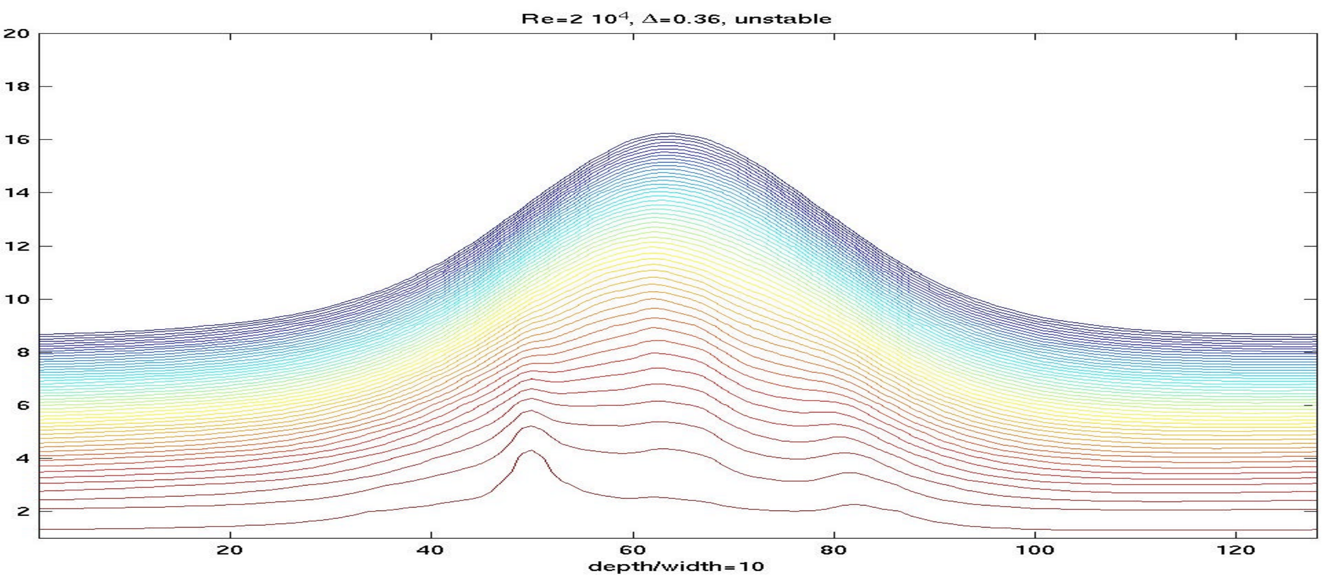

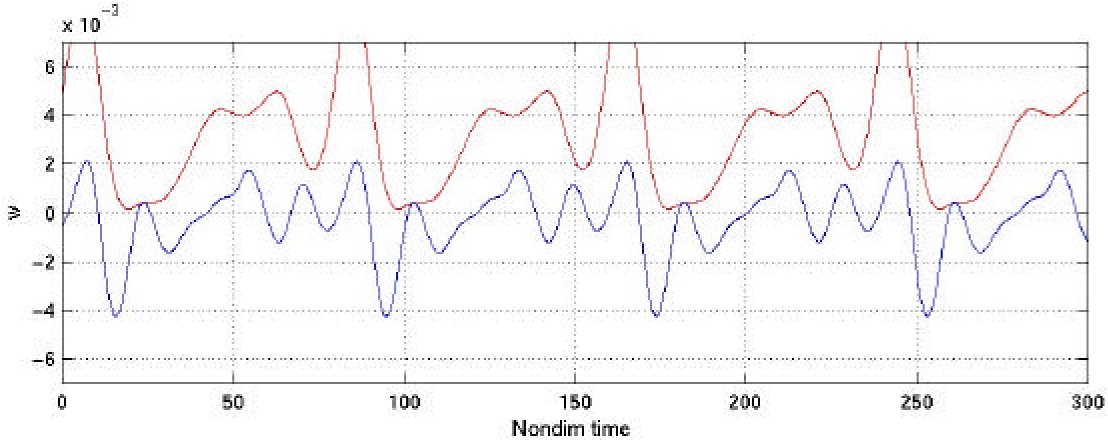

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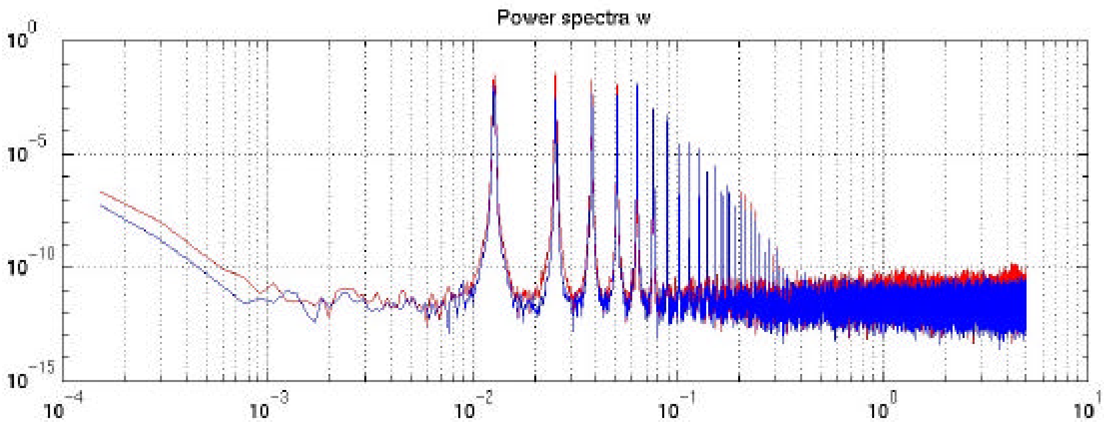

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